2.5 Surface-Altered Zeolites as Permeable Barriers for In Situ Treatment of Contaminated Groundwater

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Abstract

The current research focuses on enhanced removal of mobile metals and chlorinated hydrocarbons from contaminated water by a combination of a reduction material (represented by zero valent iron, ZVI) and a sorption material (represented by surfactant-modified zeolite, SMZ). Natural zeolite and ZVI were homogenized and pelletized to maintain favorable hydraulic properties while minimizing material segregation due to bulk density differences. The zeolite/ZVI pellets were modified with the cationic surfactant hexadecyltrimethylammonium bromide to increase contaminant sorption and, thus, the contaminant concentration on the solid surface. The chromate and perchloroethylene (PCE) degradation rates with and without surfactant modification were determined separately. The pseudo first-order reduction rate constant increased by a factor of nine for chromate and by a factor of three for PCE following surfactant modification. The enhanced contaminant reduction capacity of SMZ/ZVI pellets should allow a decrease in the amount of material required to achieve a given level of contaminant removal, while the highly porous pellets will help maintain favorable hydraulic properties in subsurface permeable barriers. Predictions based on results of the laboratory experiments indicated that chromate concentrations would be reduced below detectable levels in a 1-m-thick SMZ/ZVI barrier, while PCE levels would be reduced by four orders of magnitude.

The performance of the pellets at the pilot scale was tested in an experimental aquifer facility at the Oregon Health and Science University. The University of Dayton Research Institute prepared approximately 13 m^3 of SMZ/ZVI pellets for the pilot test.

The pellets were installed in a 6-m long by 2-m wide by 2-m deep subsurface permeable barrier in a 10-m by 10-m by 3-m deep simulated aquifer. In a five-week test, a plume of 6000 $\mu g\ L^{-1}$ of chromate and 500 $\mu g\ L^{-1}$ of PCE was injected into the pilot test tank. At the end of the test, chromate concentrations down gradient of the barrier were nondetectable; PCE concentrations had been reduced by about two orders of magnitude. The plume was fully captured, with no bypass under or around the barrier, indicating that the desired hydraulic conductivity contrast between the barrier and aquifer material was maintained during the test. The less than expected reduction in PCE concentrations appeared due to variability in the bulk-produced pellets manufactured for the pilot test. Refinements in the bulk-production process should create a pellet with significantly enhanced contaminant reduction characteristics, along with improved hydraulic properties, compared to other candidate permeable barrier materials.

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University of Dayton Research Institute

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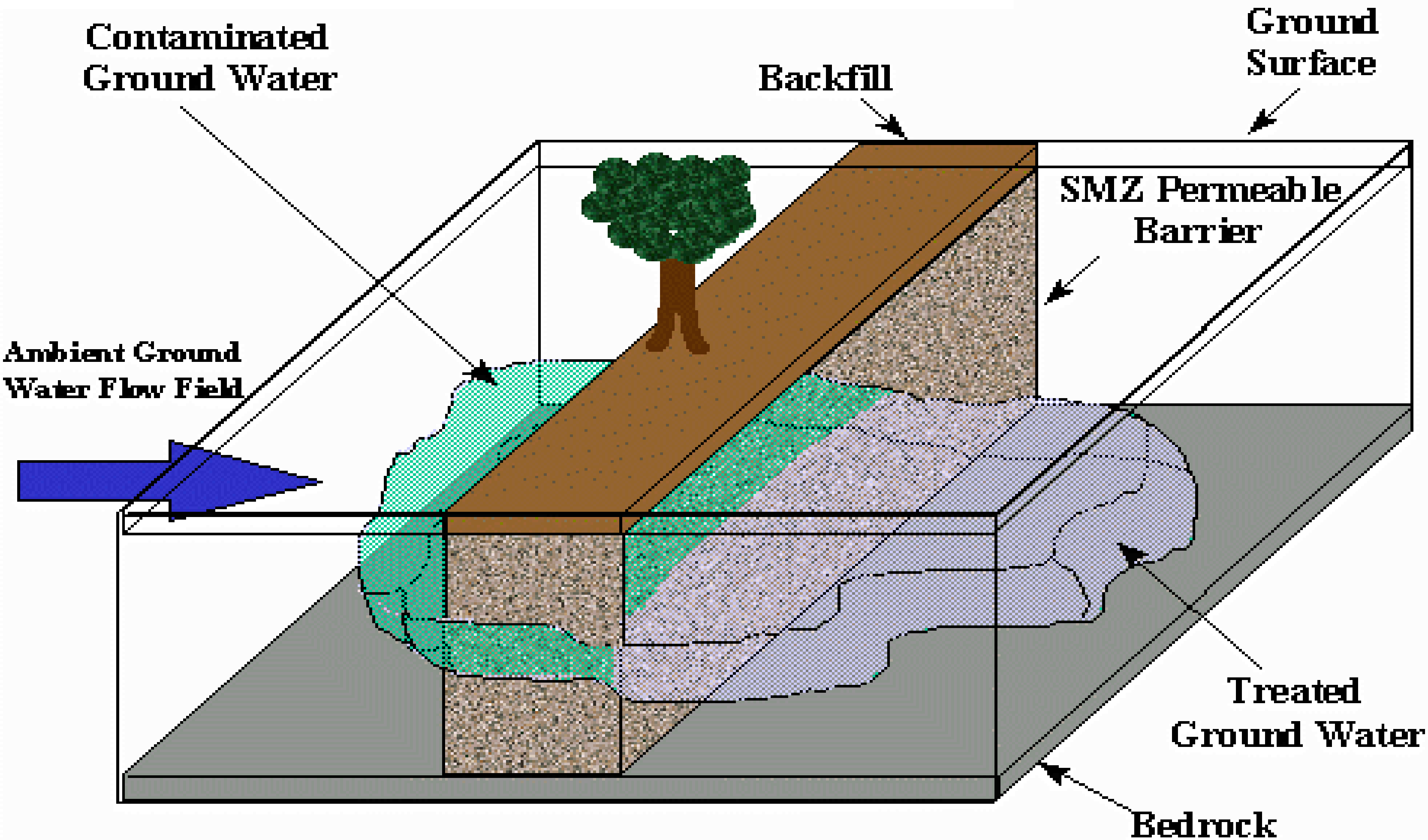
National Energy Technology Laboratory

Permeable Barrier



Outline

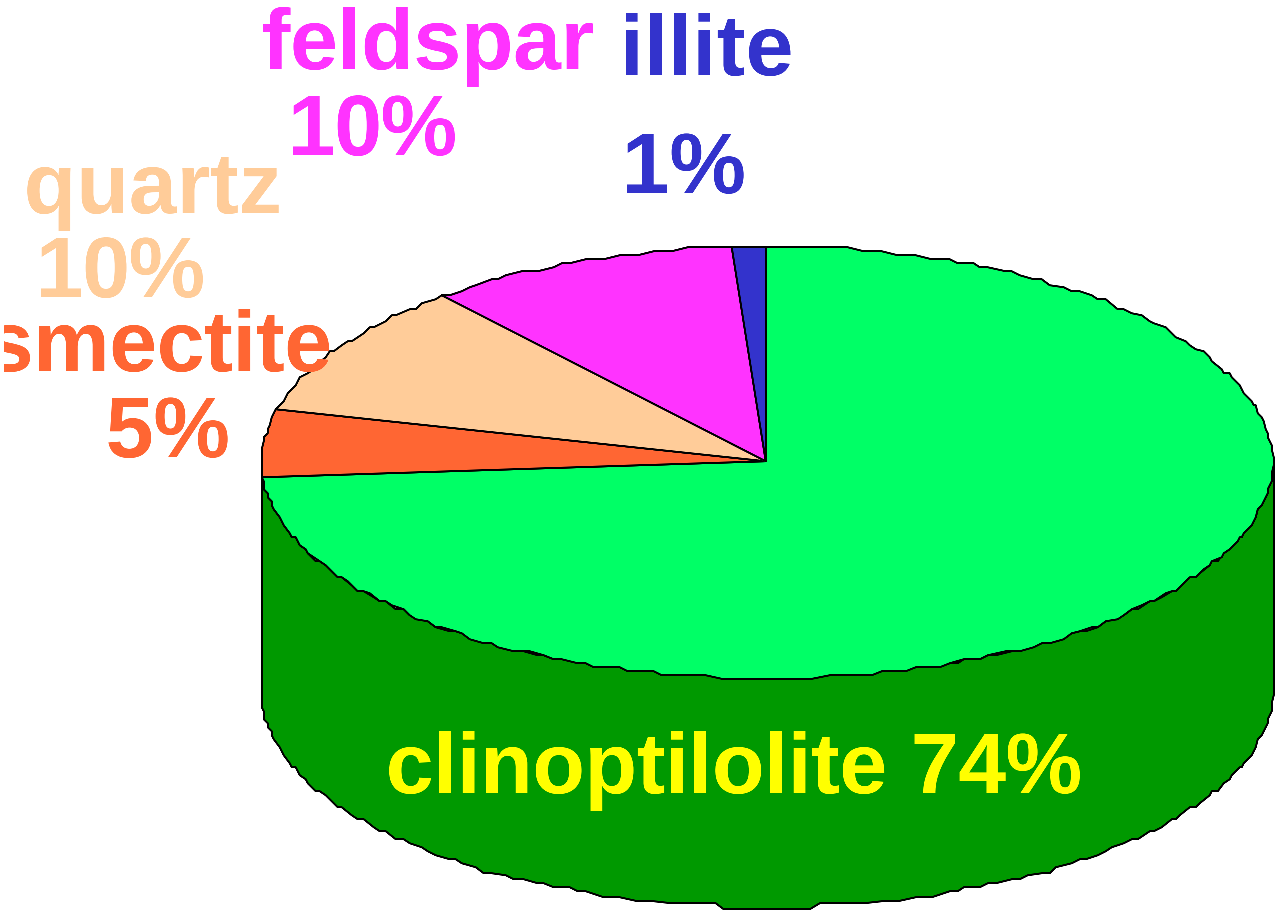
PREVIOUS PROJECT PHASES

- Development of SMZ
- Pilot testing of SMZ

CURRENT PROJECT PHASE

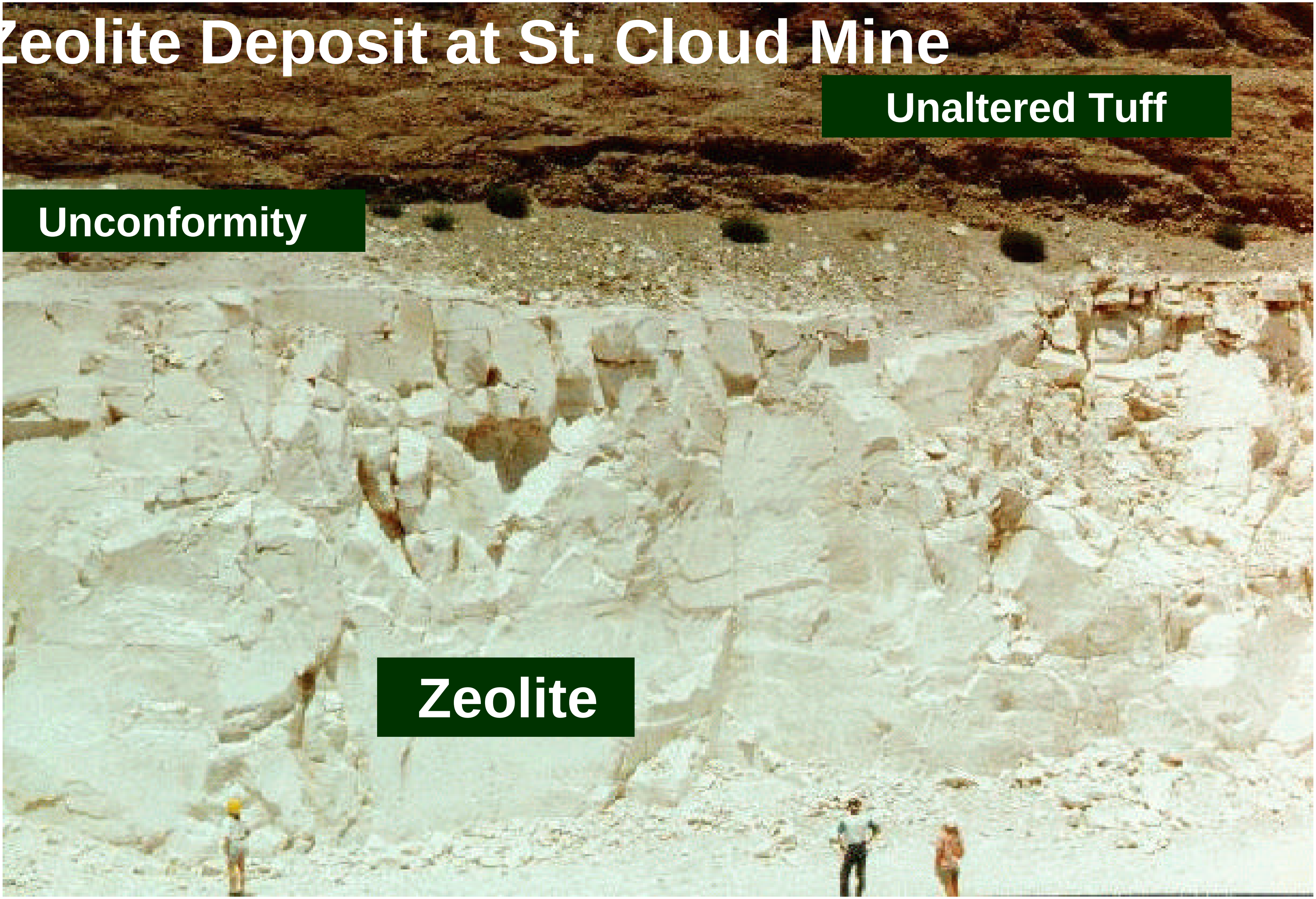
- Development of SMZ/ZVI pellets
- Lab testing of SMZ/ZVI pellets
- Pilot testing of SMZ/ZVI pellets
- Project schedule

Zeolite Properties

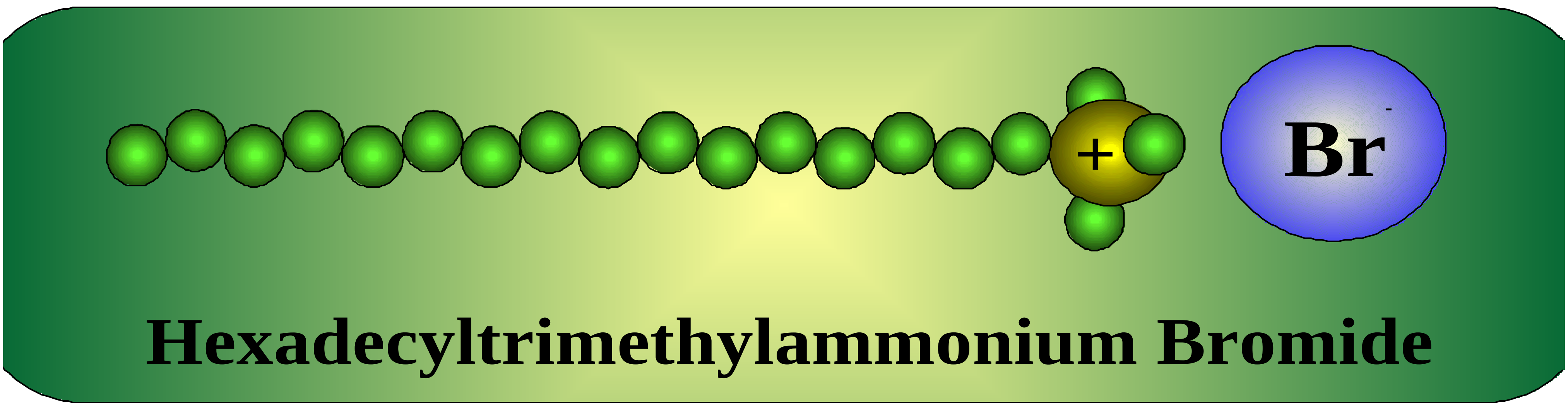


- High surface area
- High internal and external cation exchange capacity
- Can be tailored to any particle size/permeability

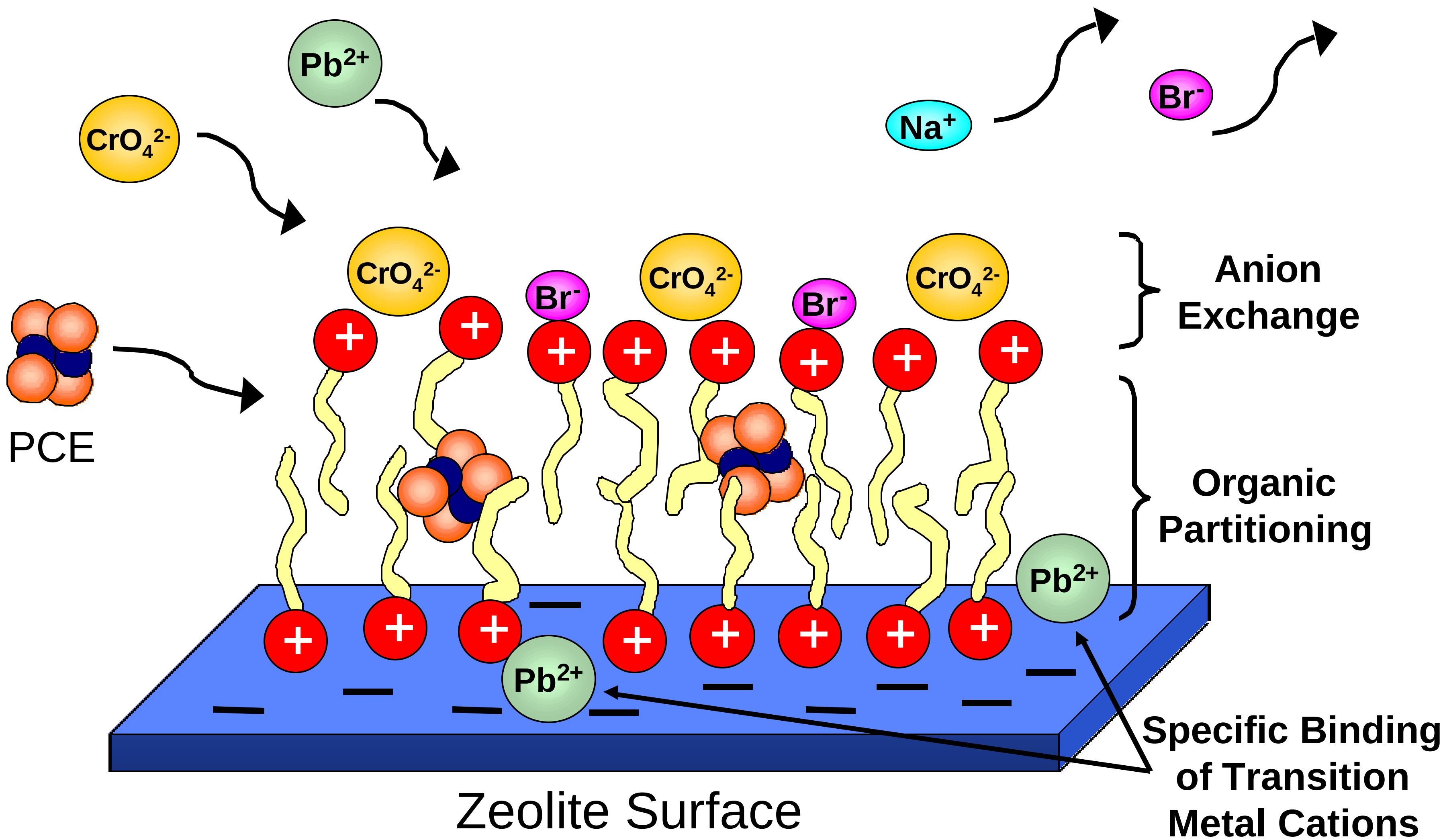
Zeolite Deposit at St. Cloud Mine



HDTMA - A Cationic Surfactant



SMZ Retention Mechanisms



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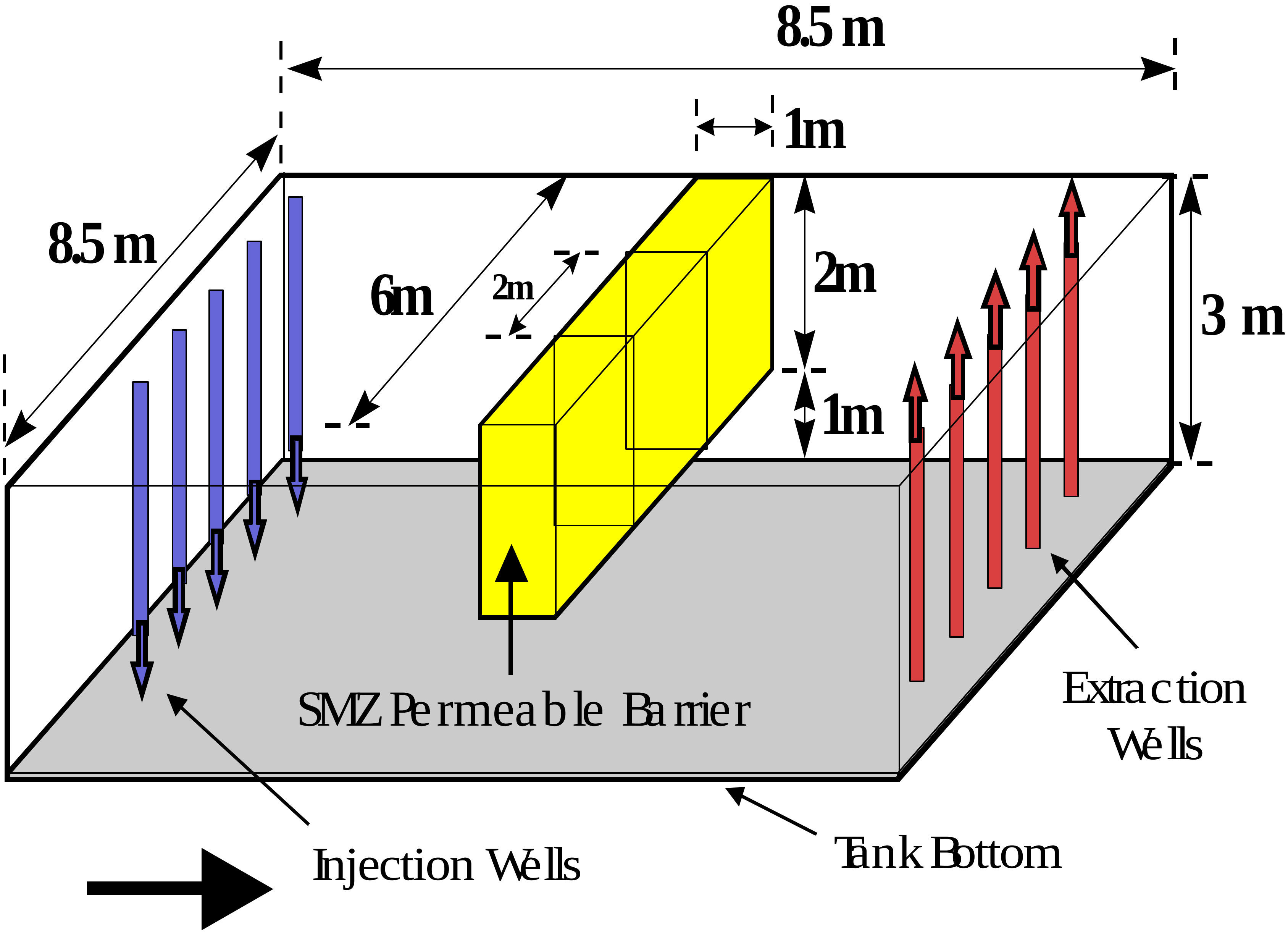
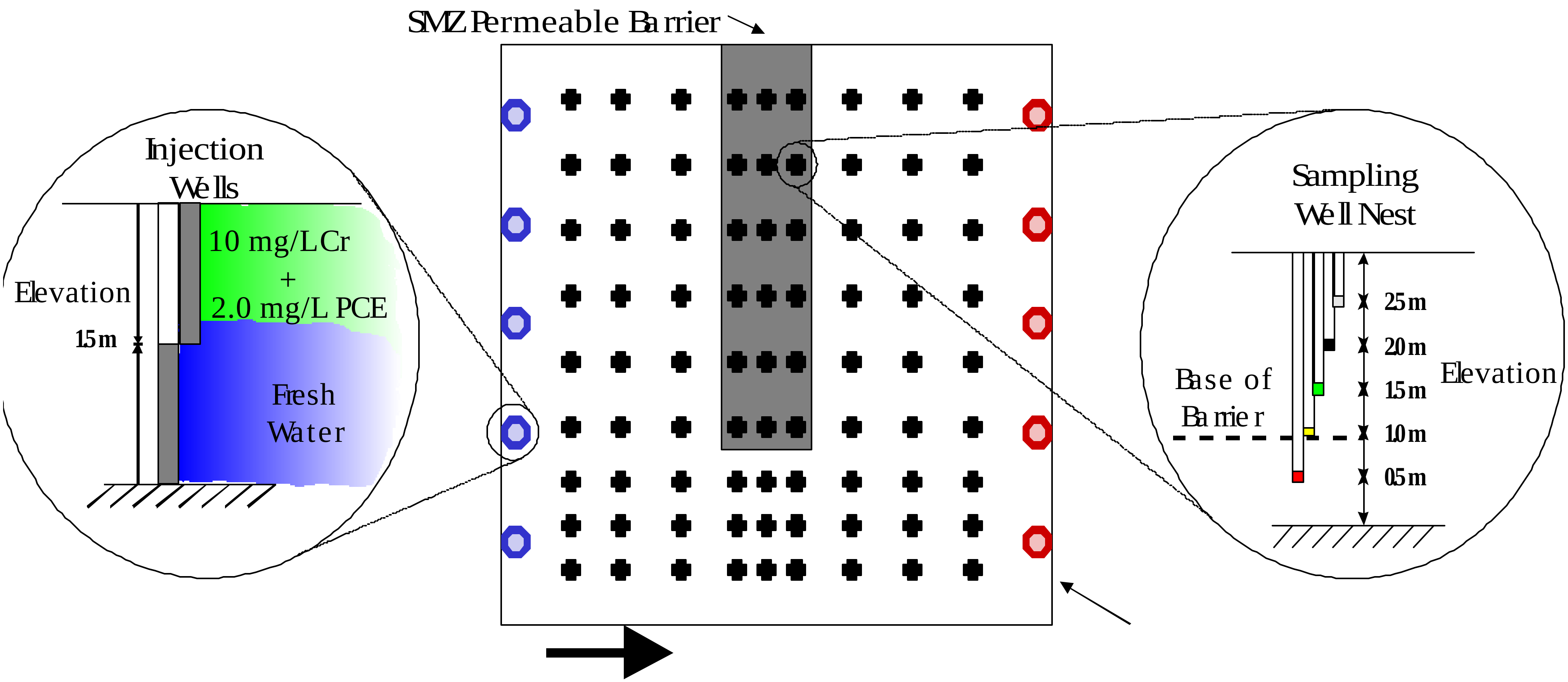
Pilot Scale Study Tank at OGI

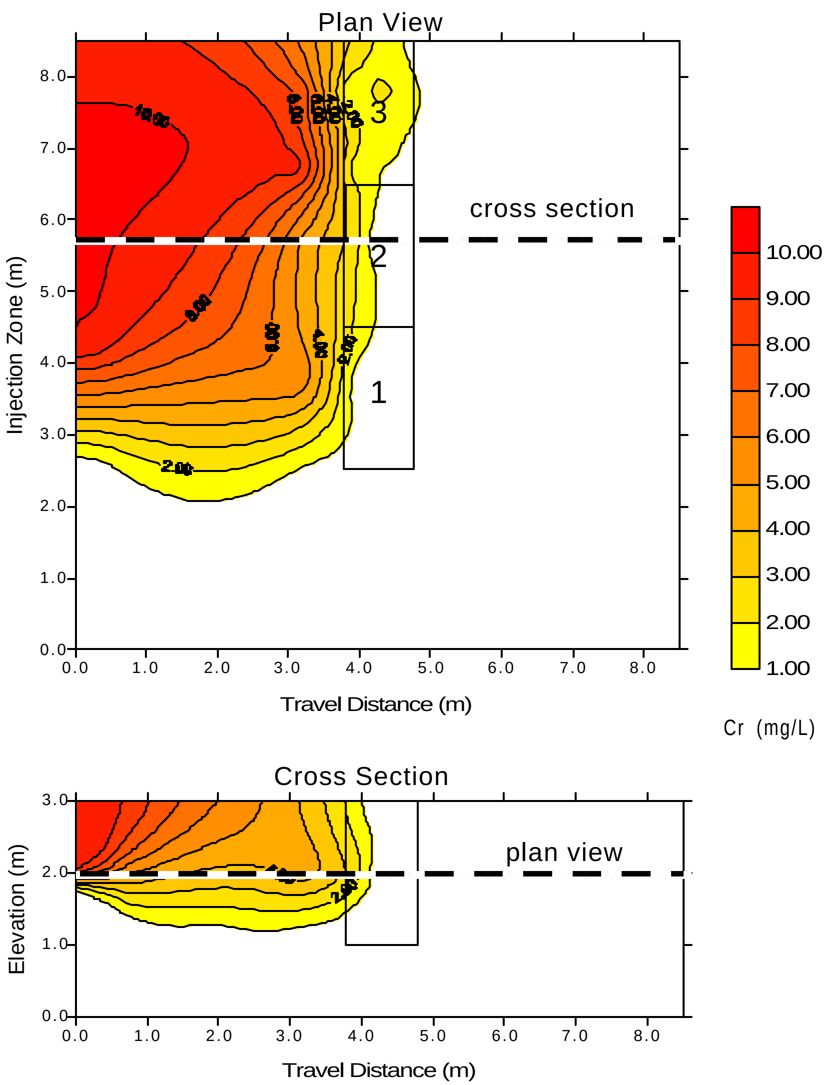


Sample Well Locations

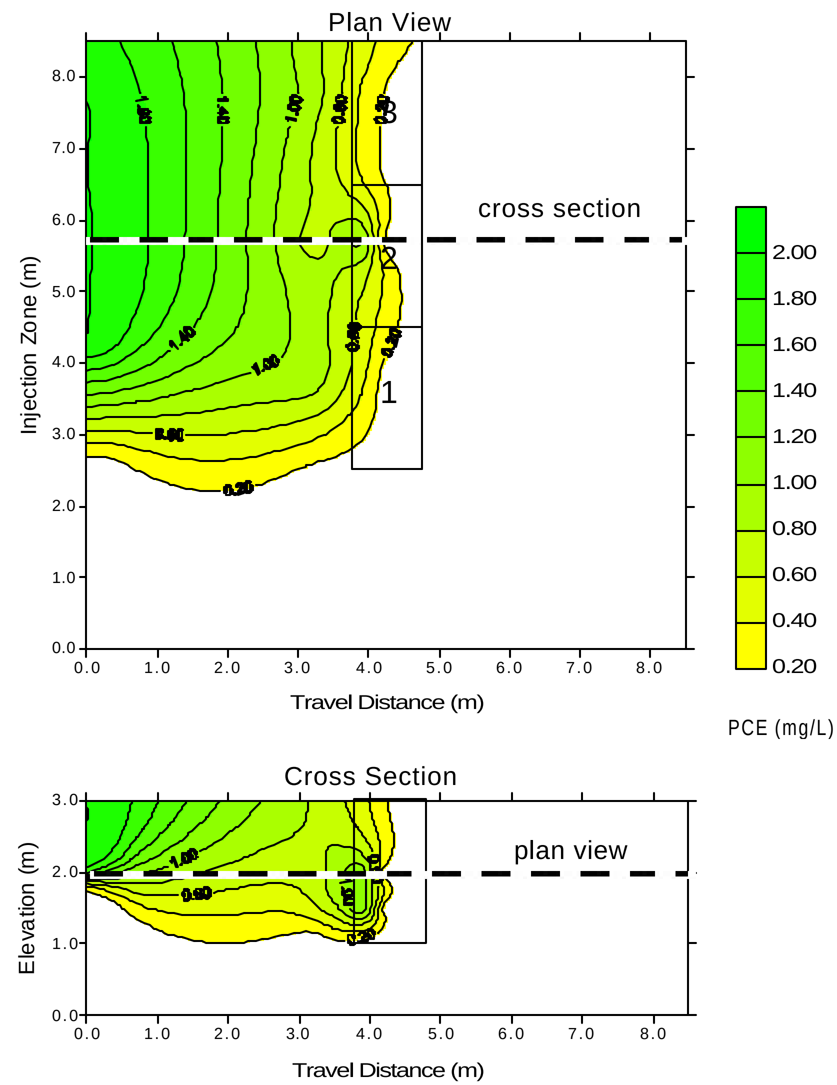


Cr and PCE Distributions, Day 41

Cr Distribution after 41 days of injection (8/20/98)



PCE Distribution after 41 days of injection (8/20/98)



Pilot Test R vs. Lab R

	PCE	CrO_4^{2-}
Retardation Factor	$R = 1 + \frac{rK_D}{q}$	$R = 1 + \frac{rK_L b}{q(1+K_L C)}$ (assuming C=10 mg L^{-1})
Lab R	**29**	**42**
Pilot Test R	**39**	**44**

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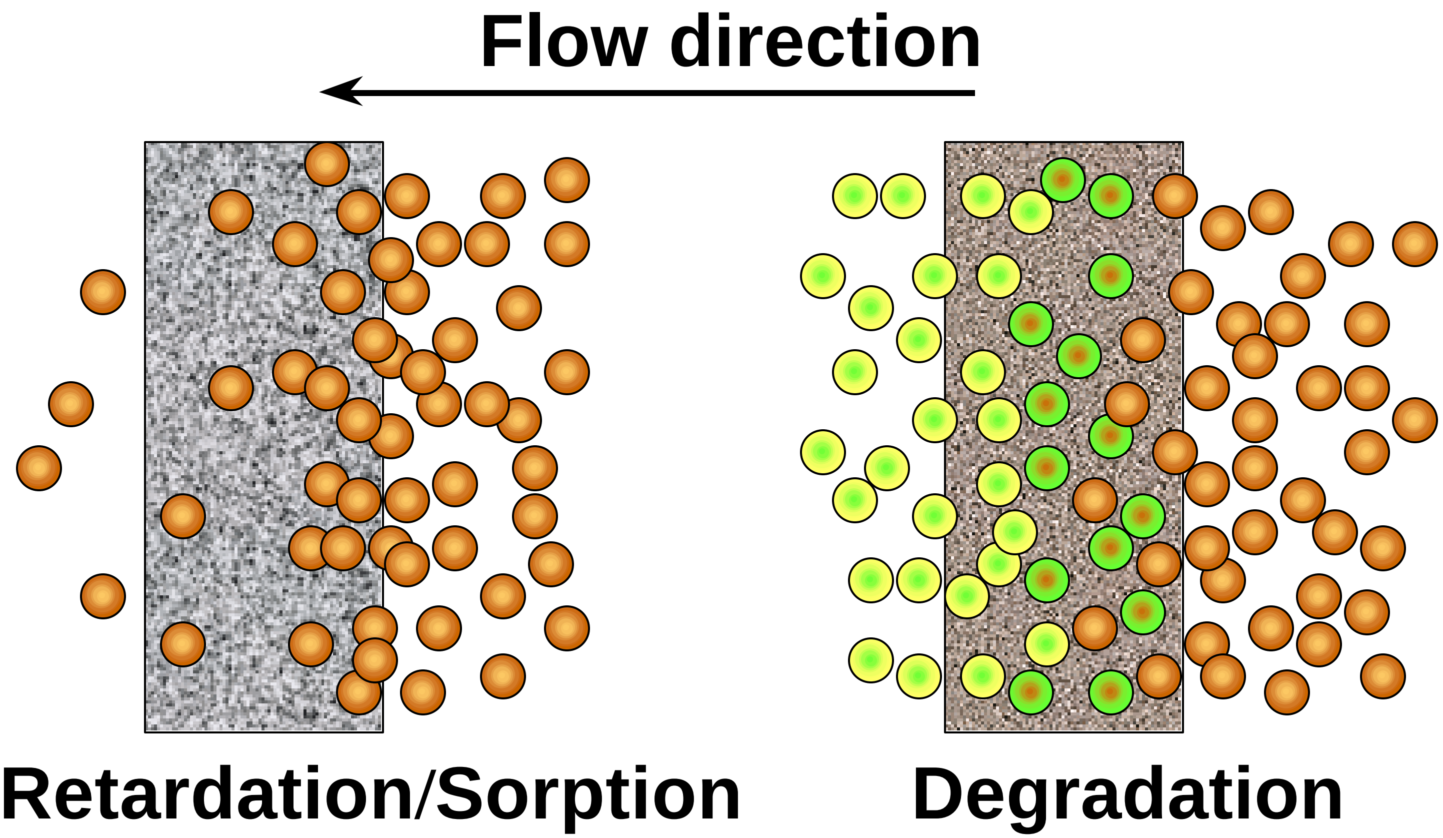
Permeable Barriers Types

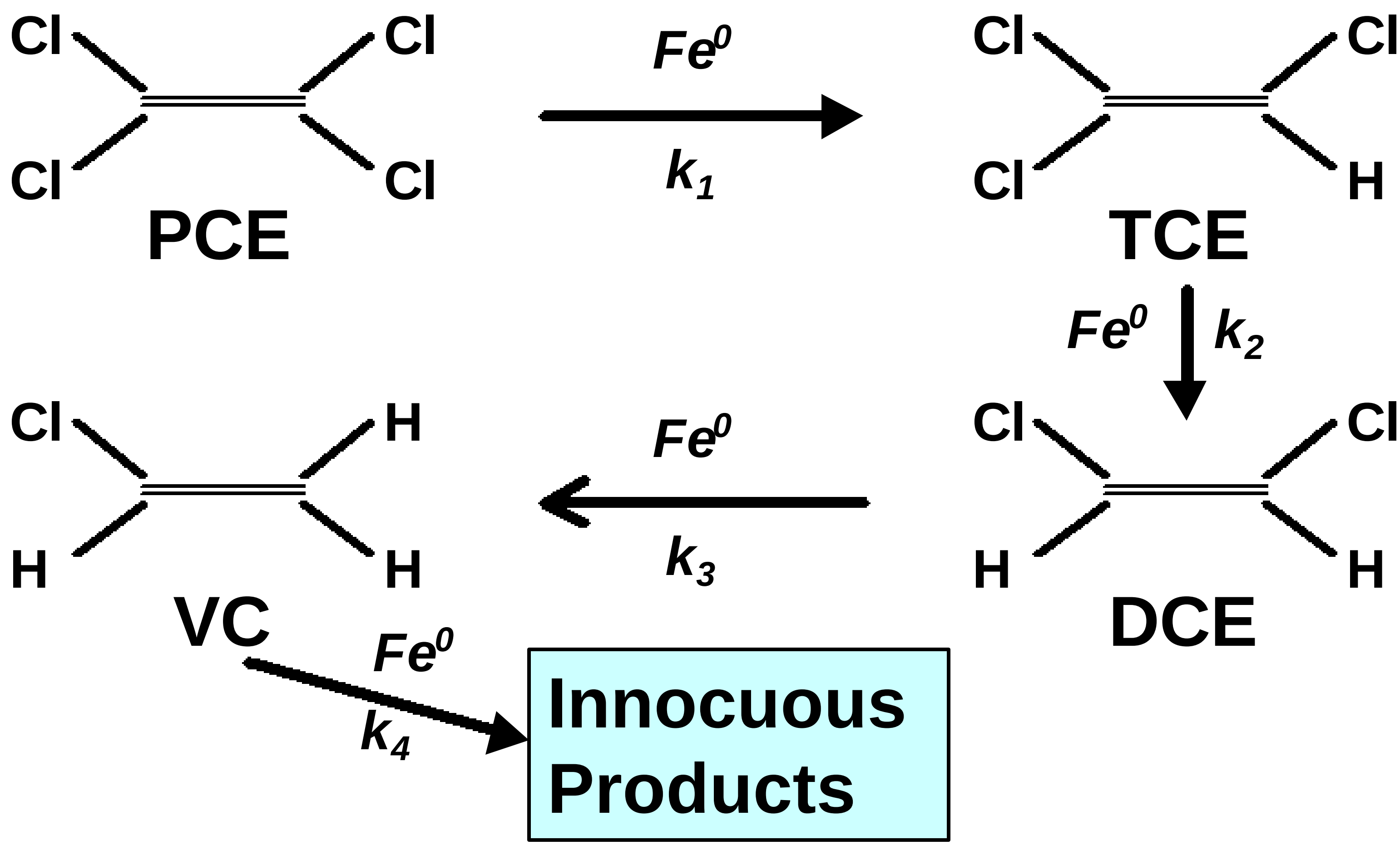


Chromate Reduction by ZVI

$$Cr^{VI} \xrightarrow[k_{Cr}]{Fe^{0}} Cr^{III}$$

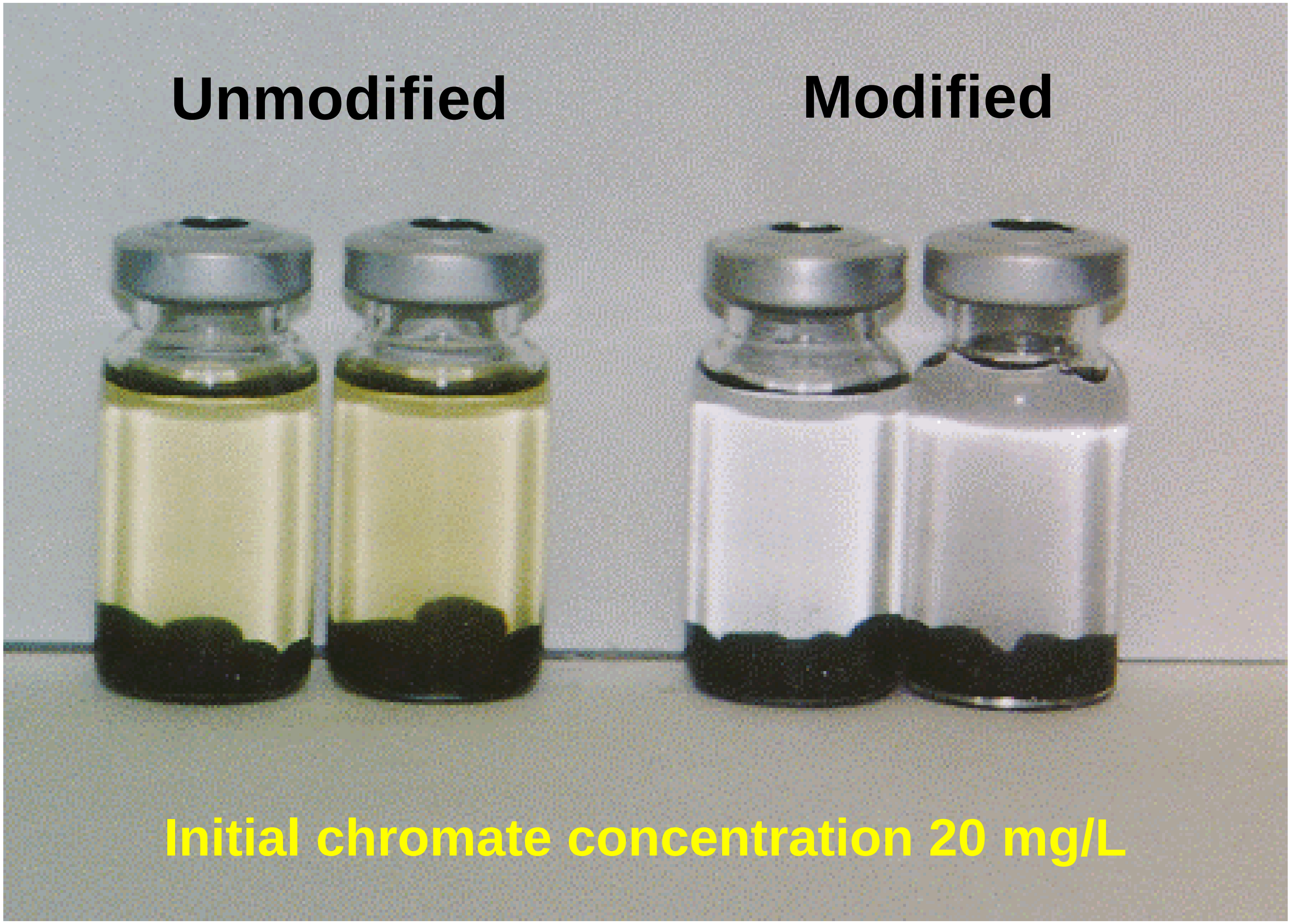
soluble, mobile	**insoluble, sorbed**

Chlorinated HC Reduction by ZVI

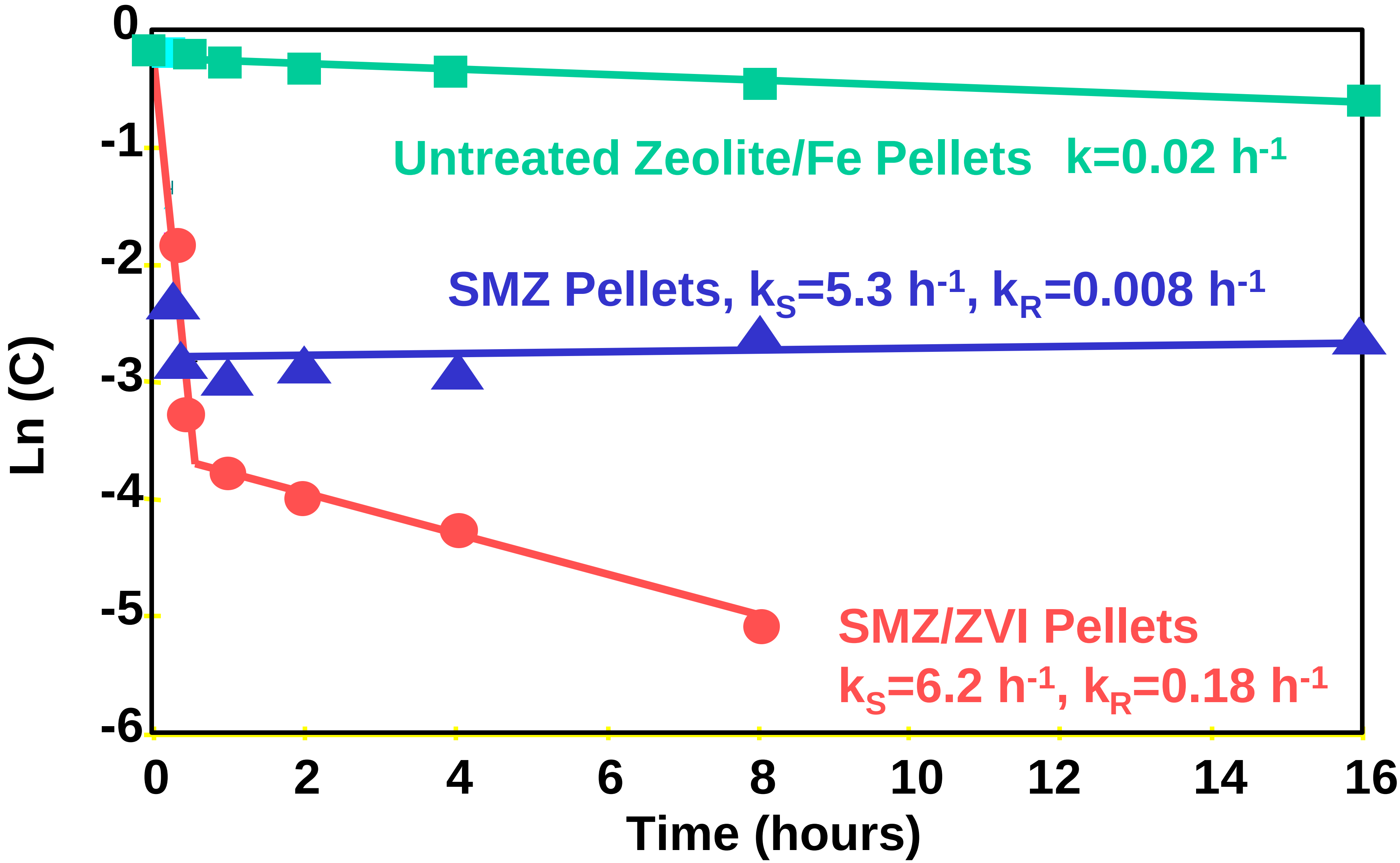


SMZ/ZVI Pellets

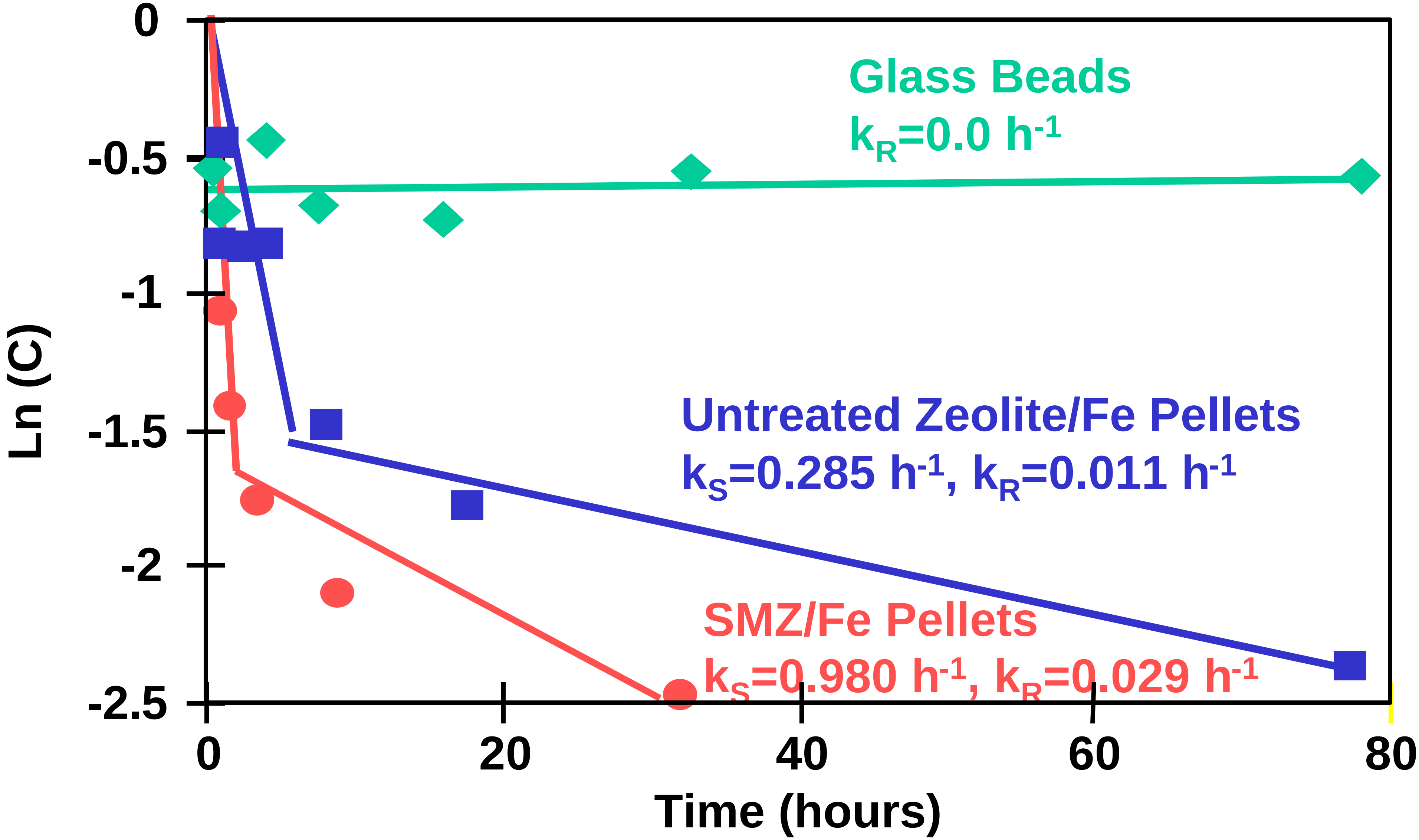
Cr (VI) Sorption/Reduction by SMZ/ZV



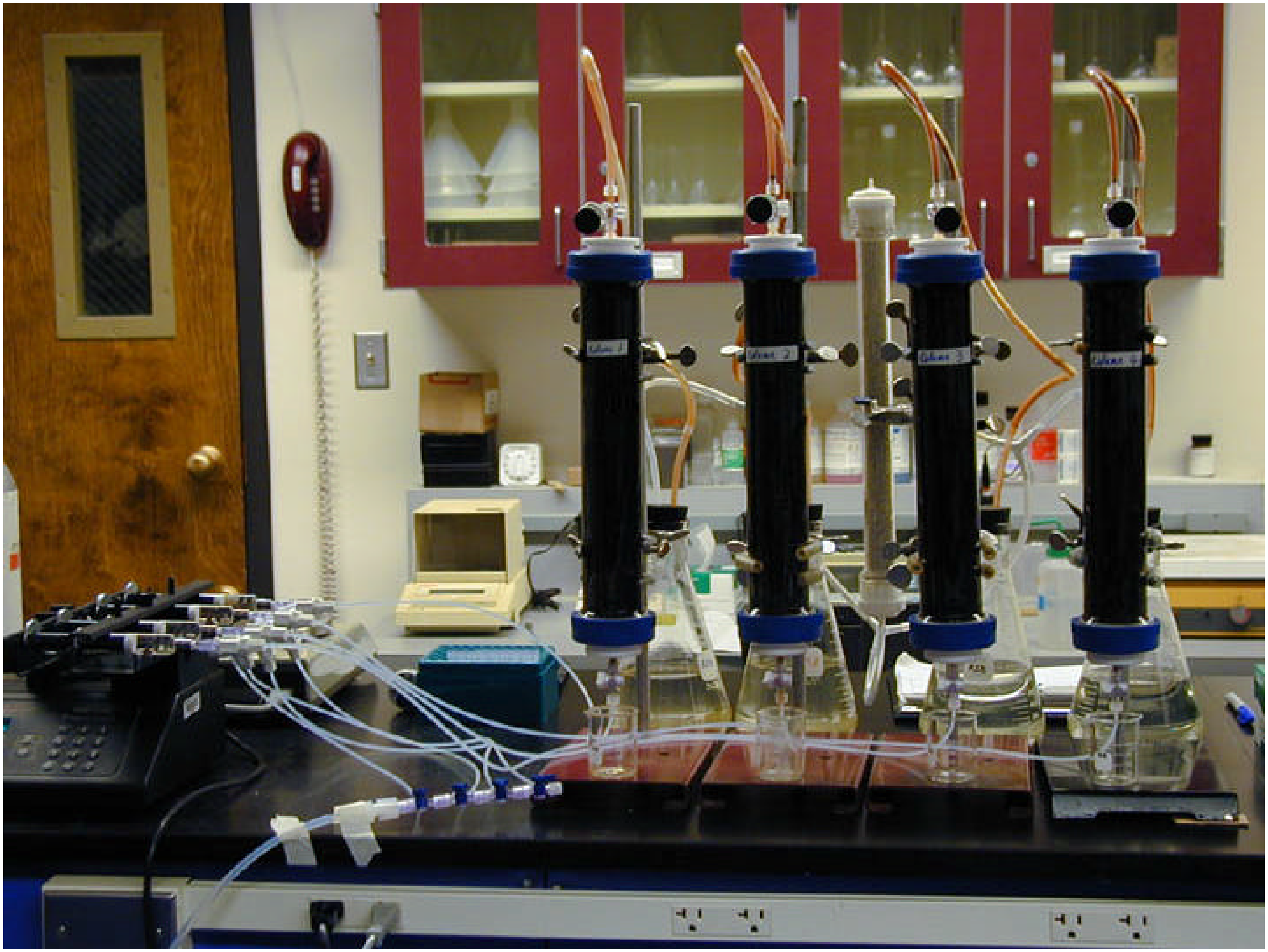
Chromate Reduction Kinetics



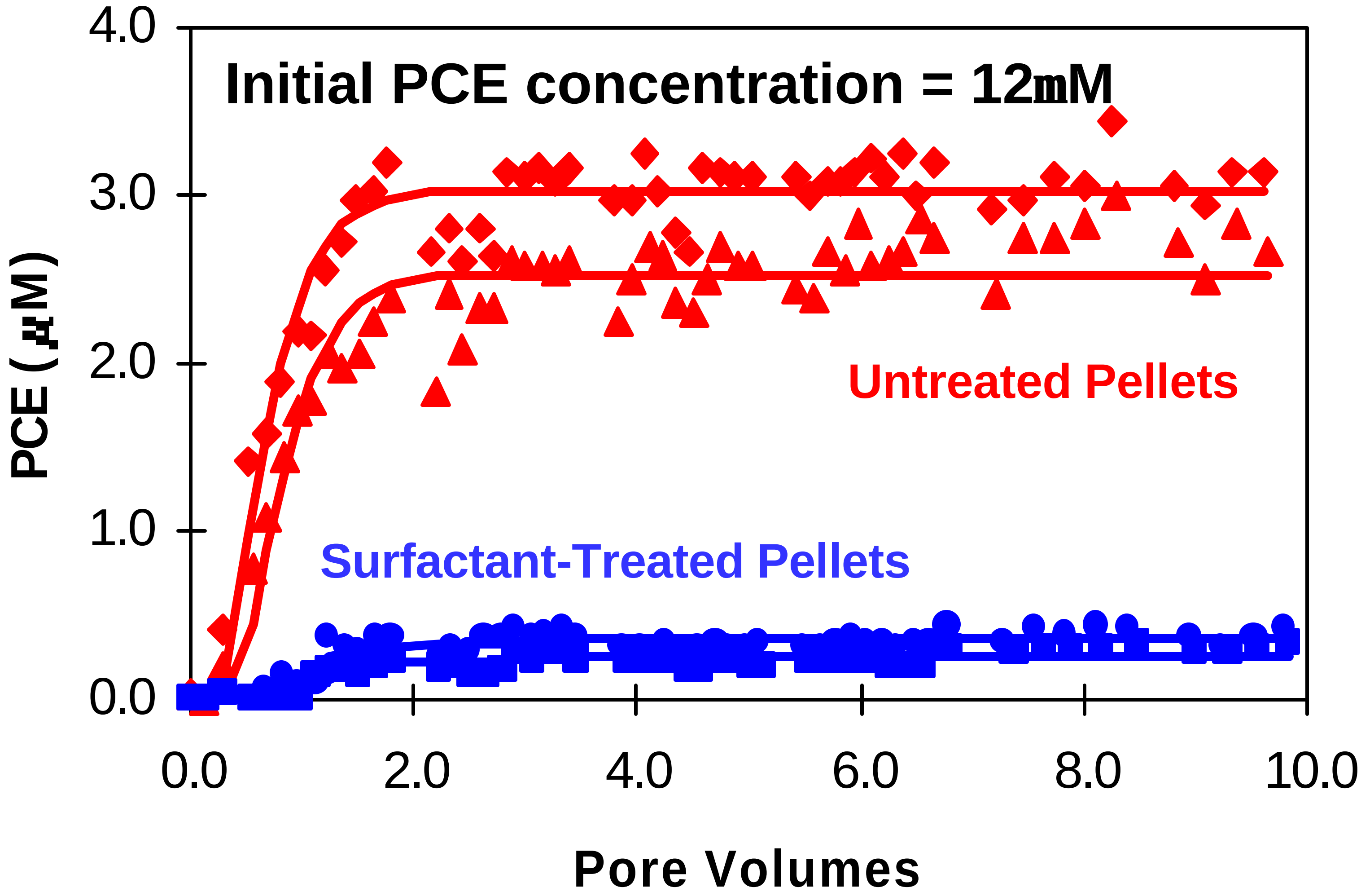
PCE Reduction Kinetics



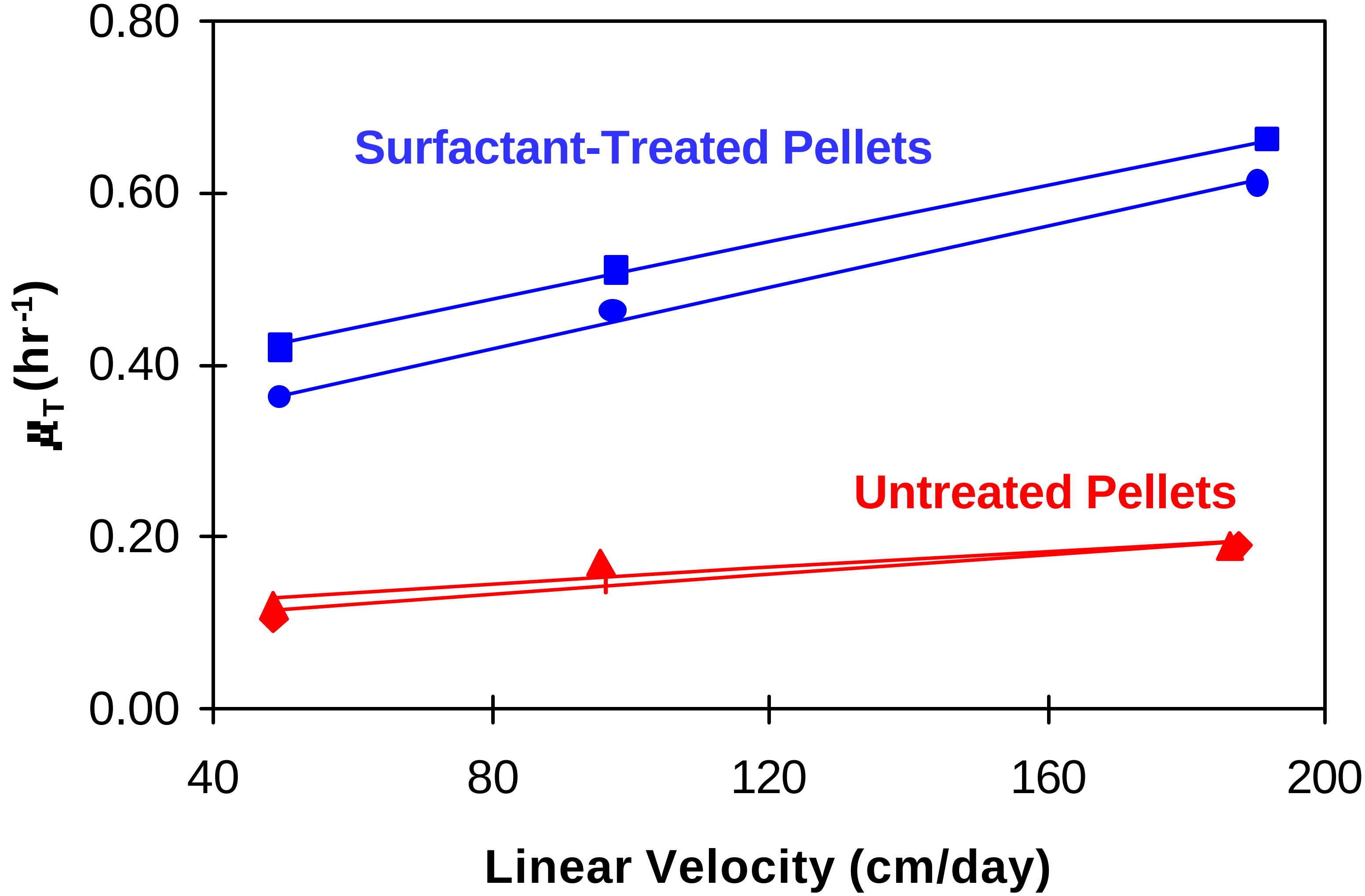
SMZ/ZVI Testing in Lab Columns



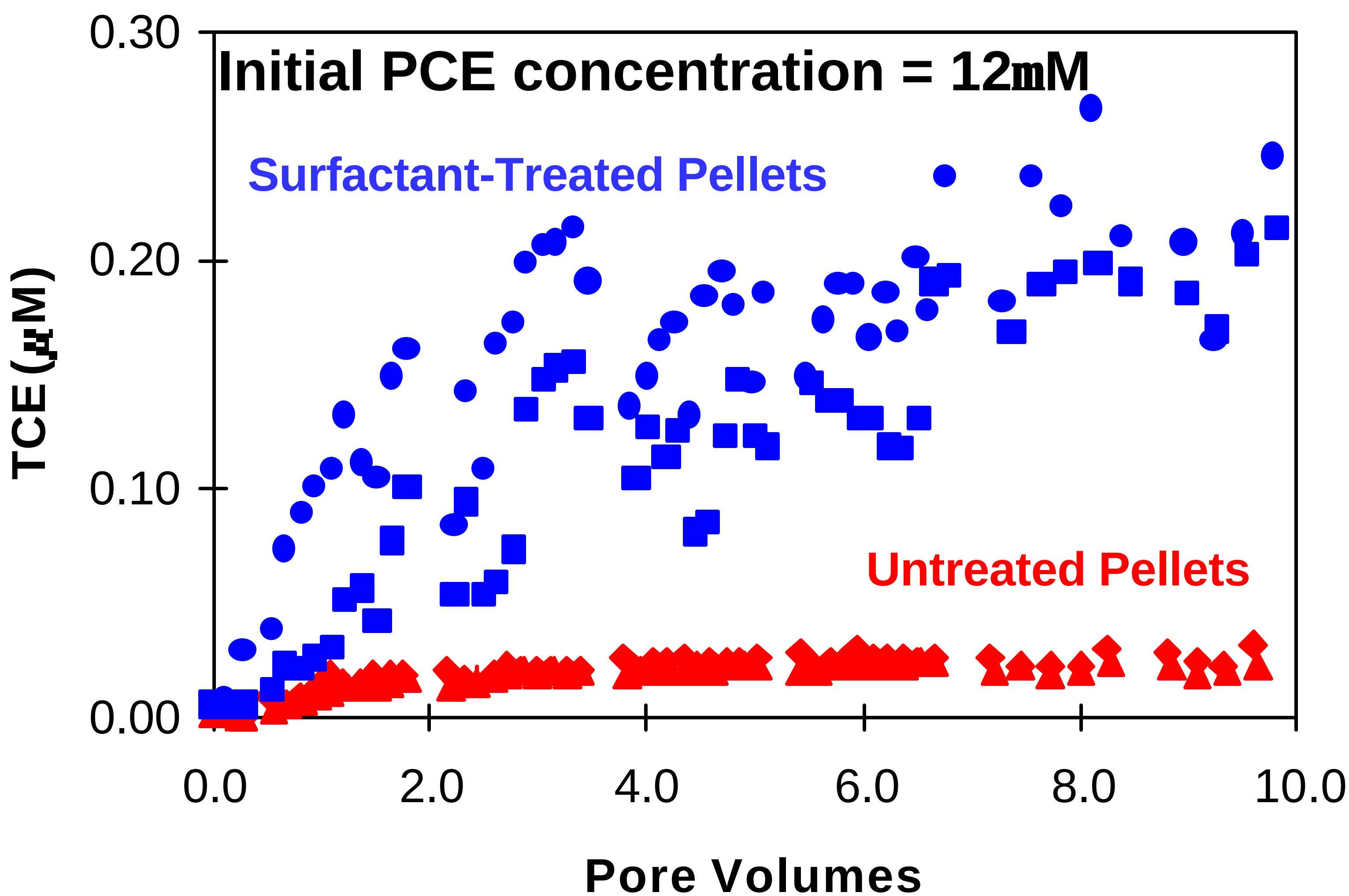
PCE Reduction by Fe/SMZ



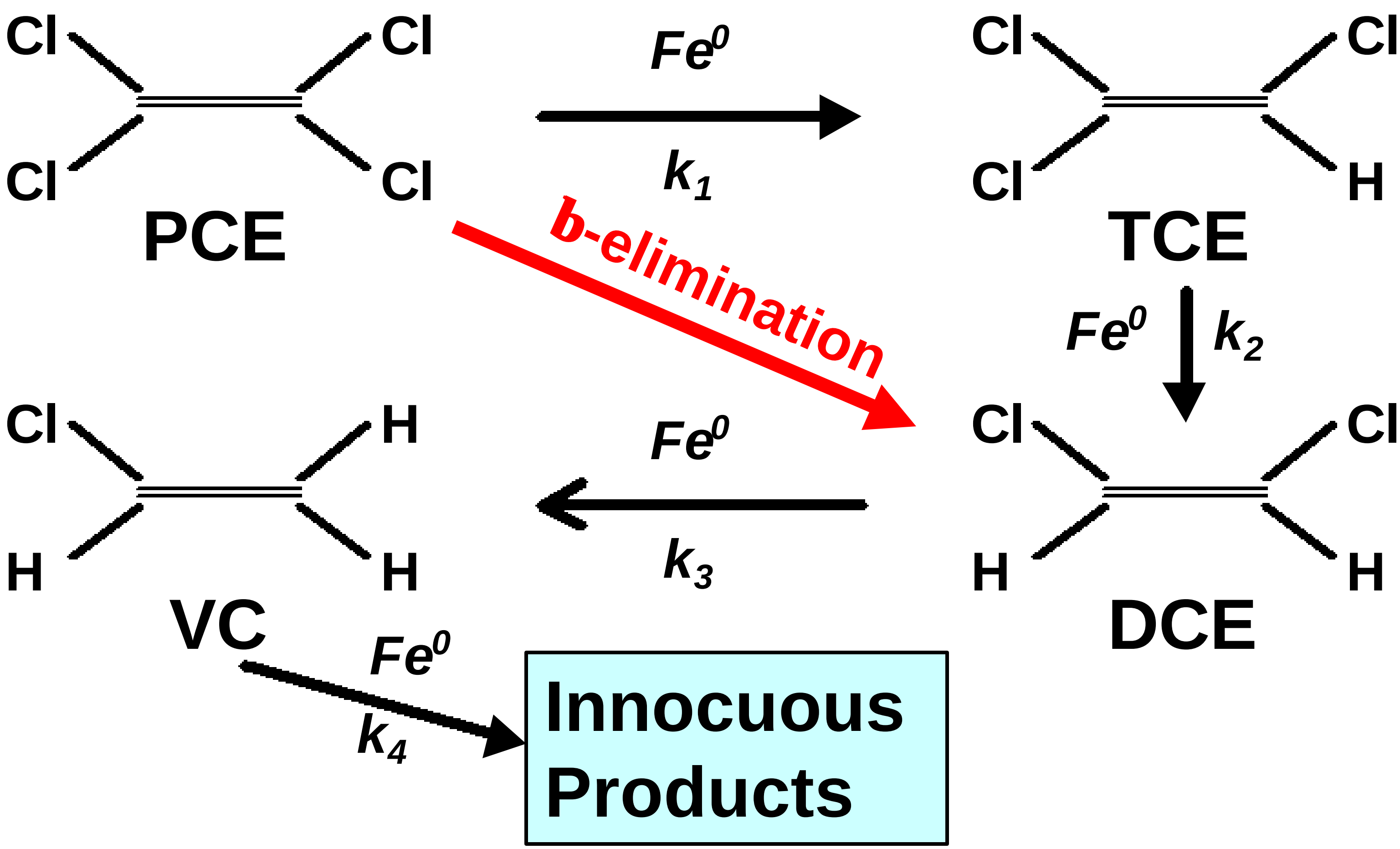
PCE Reduction Rate vs. Velocity



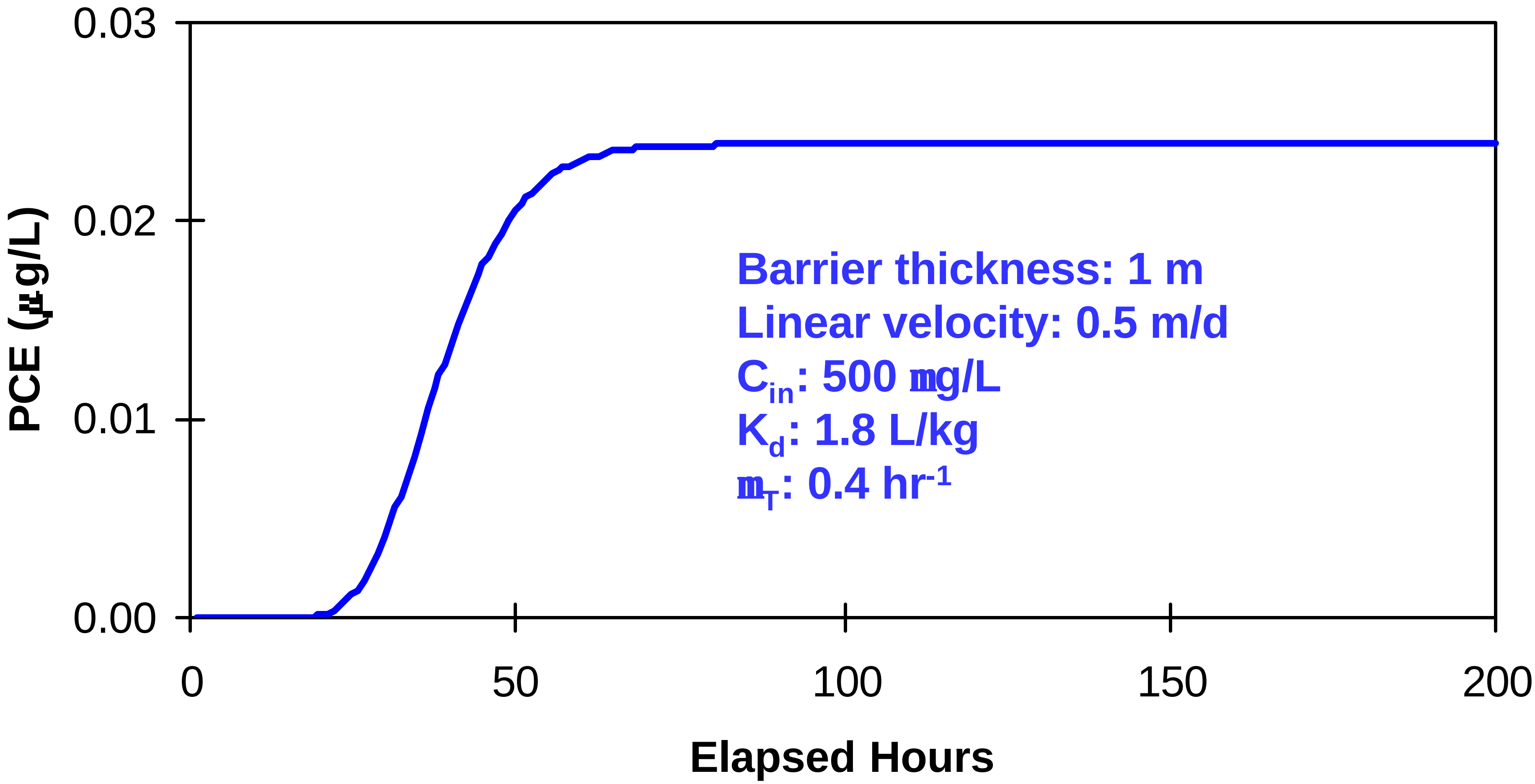
TCE Produced from PCE Reduction



Chlorinated HC Reduction



PCE Breakthrough in SMZ/ZVI Barrie



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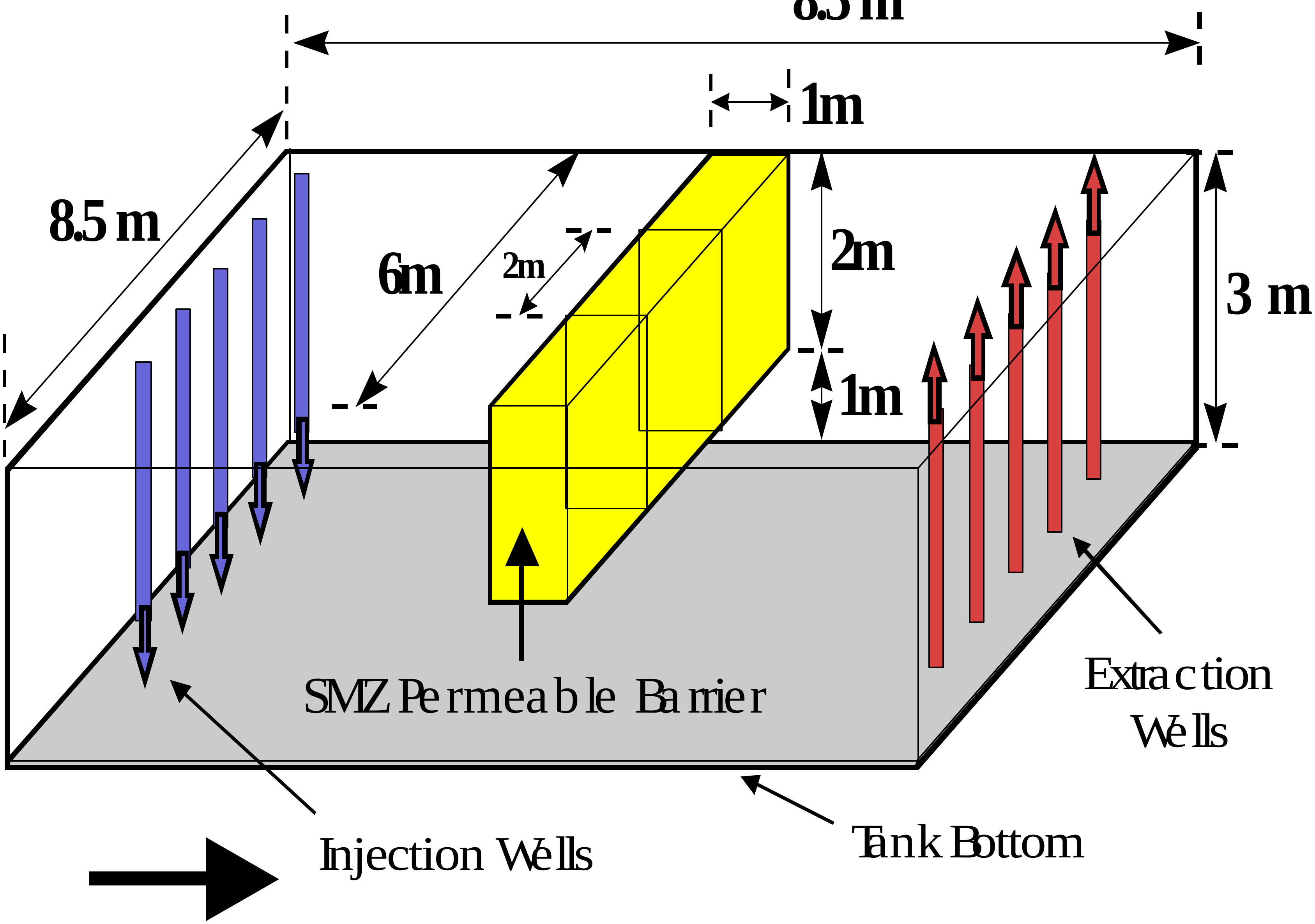
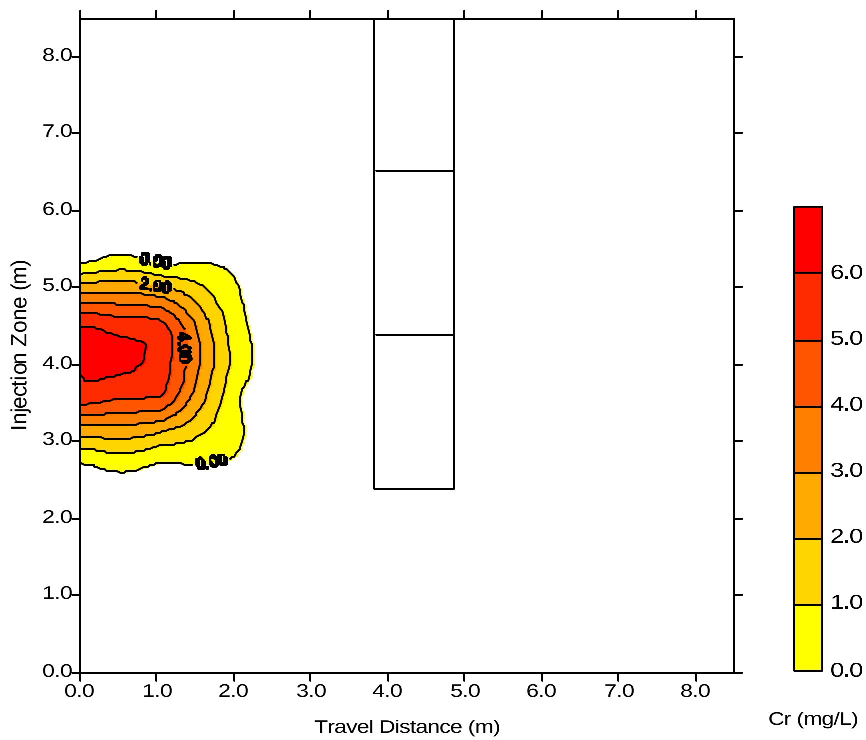


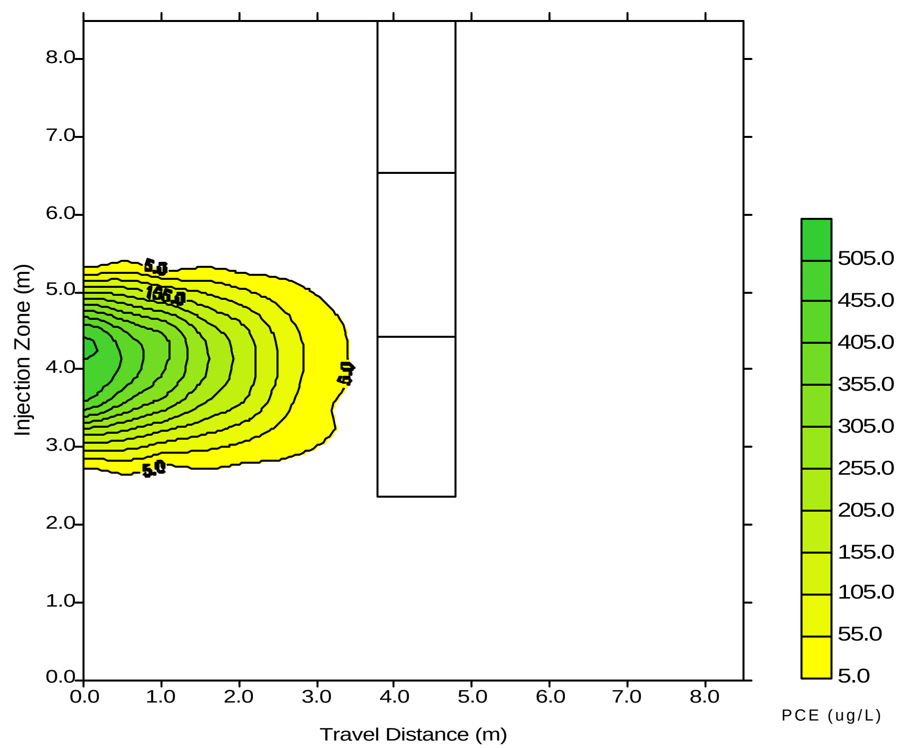
SMZ/ZVI Cubes in Barrier

Cr and PCE Distributions, 1st week

Cr Distribution after 3 days of injection (7/02/2001)
Depth=1.0m
Plan View

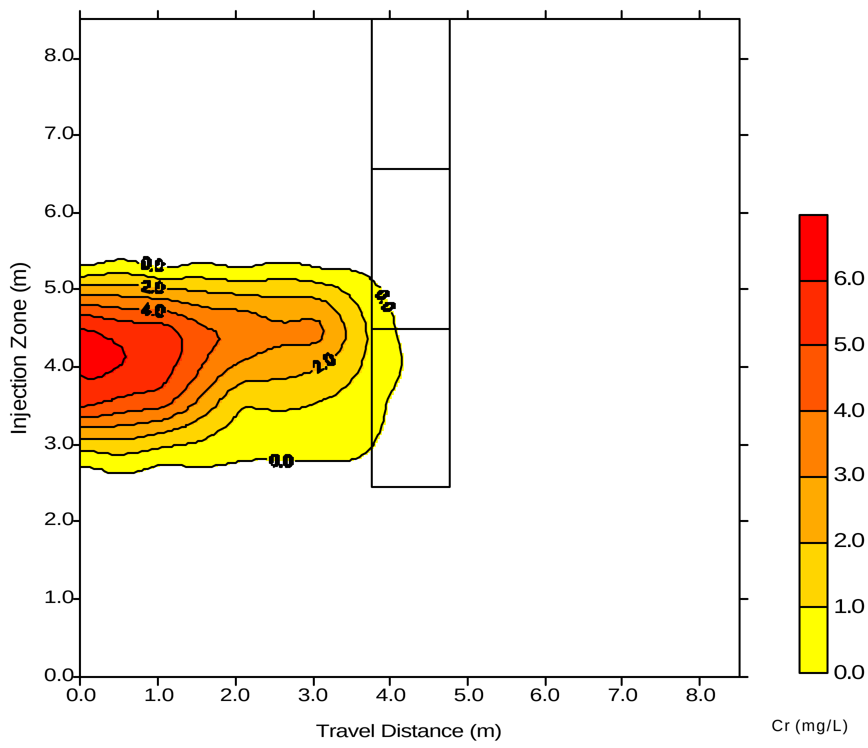


PCE Distribution after 6 days of injection (7/02/2001)
Depth=1.0m
Plan View

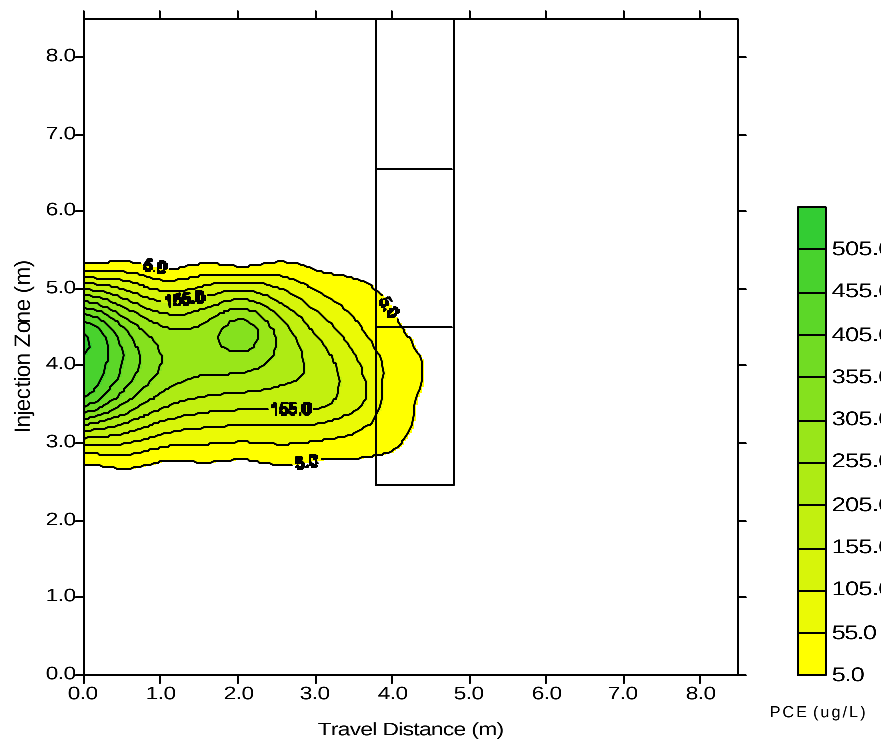


Cr and PCE Distributions, 2nd week

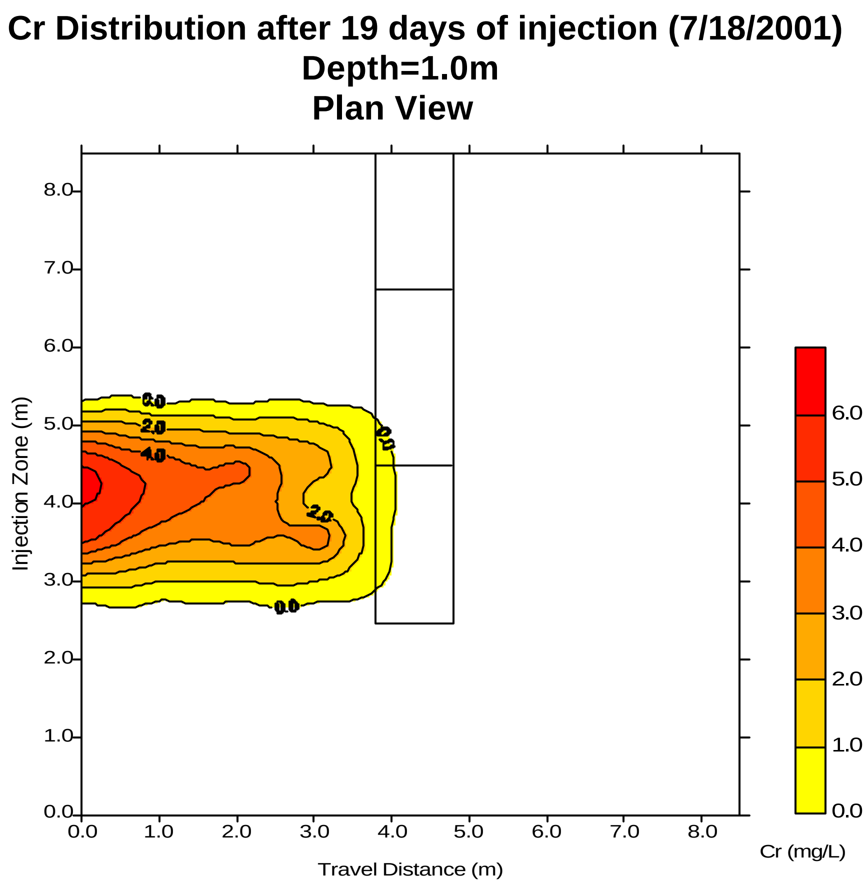
Cr Distribution after 12 days of injection (7/11/2001)
Depth=1.0m
Plan View

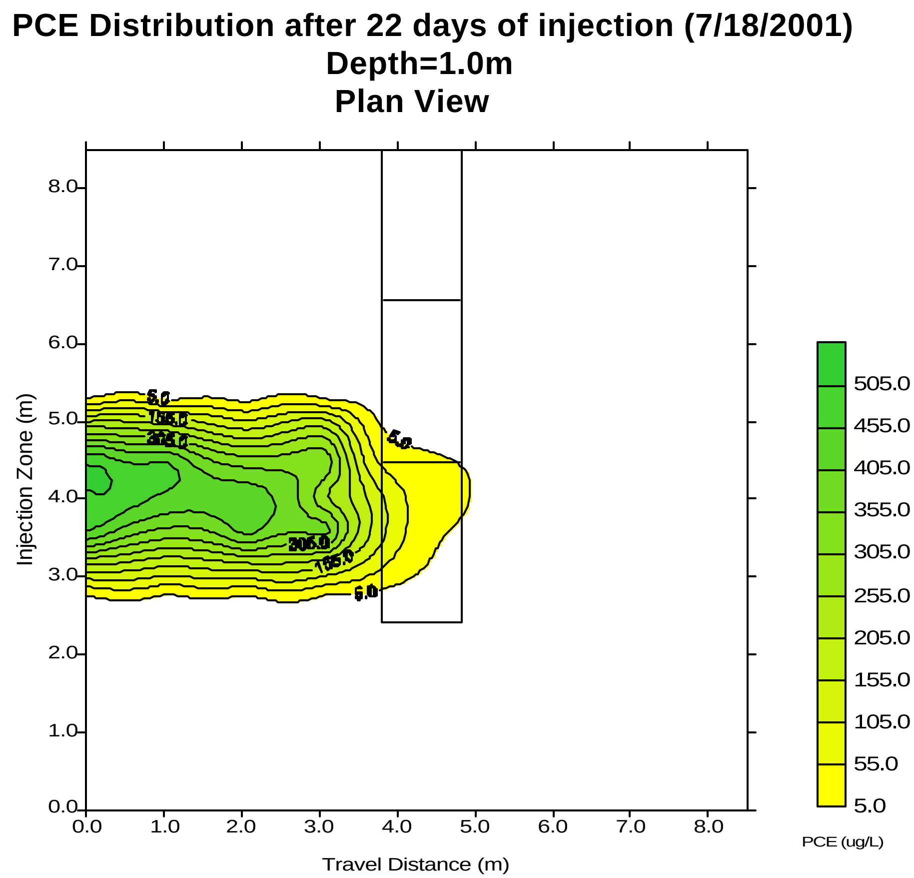


PCE Distribution after 15 days of injection (7/11/2001)
Depth=1.0m
Plan View



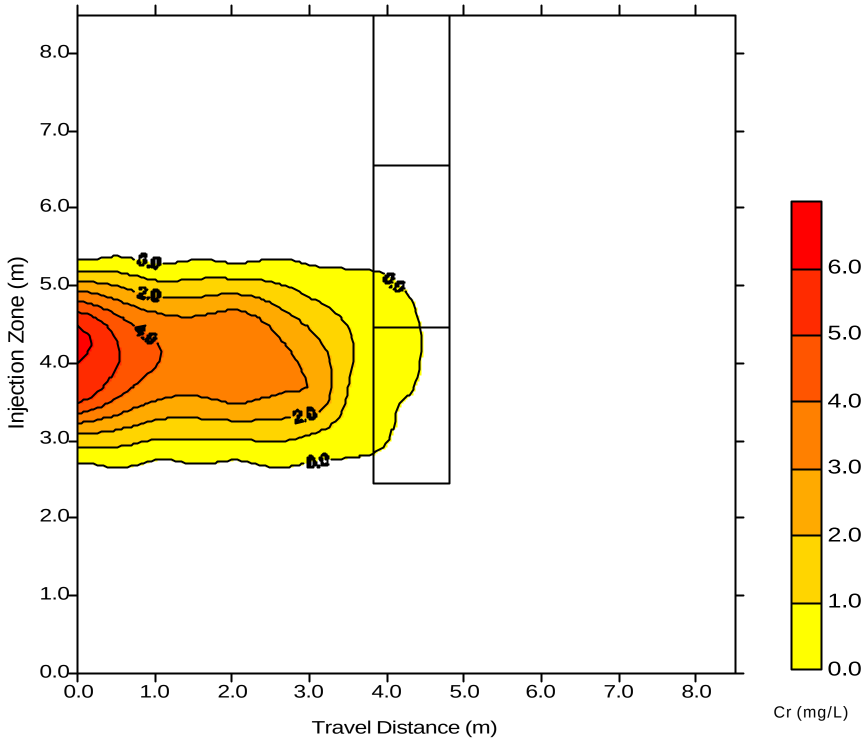
Cr and PCE Distributions, 3rd week



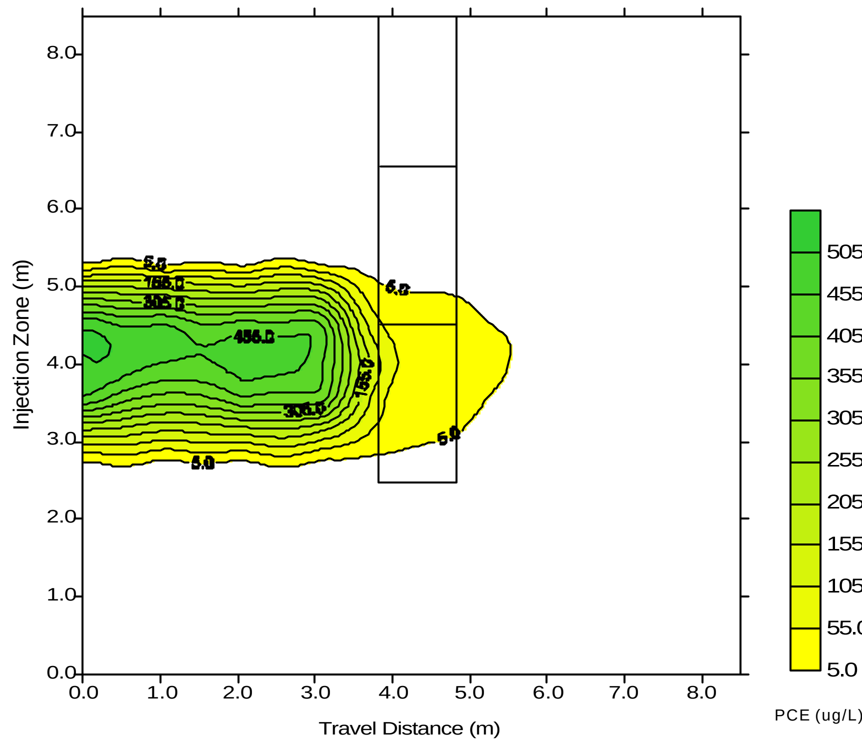


Cr and PCE Distributions, 4th week

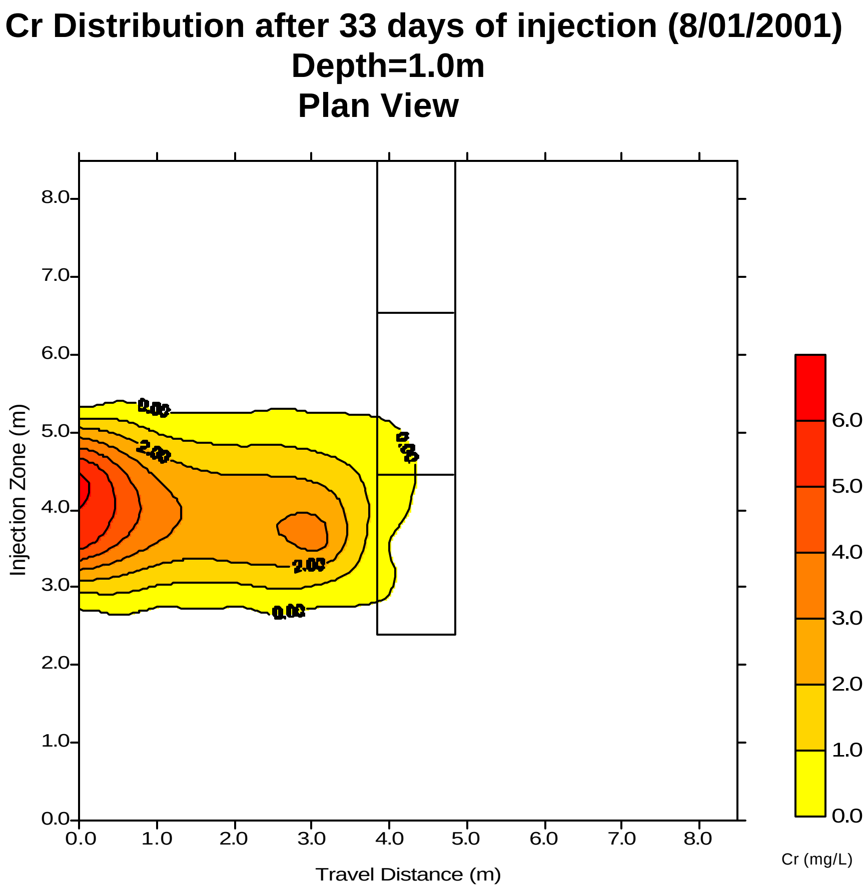
Cr Distribution after 26 days of injection (7/25/2001)
Depth=1.0m
Plan View

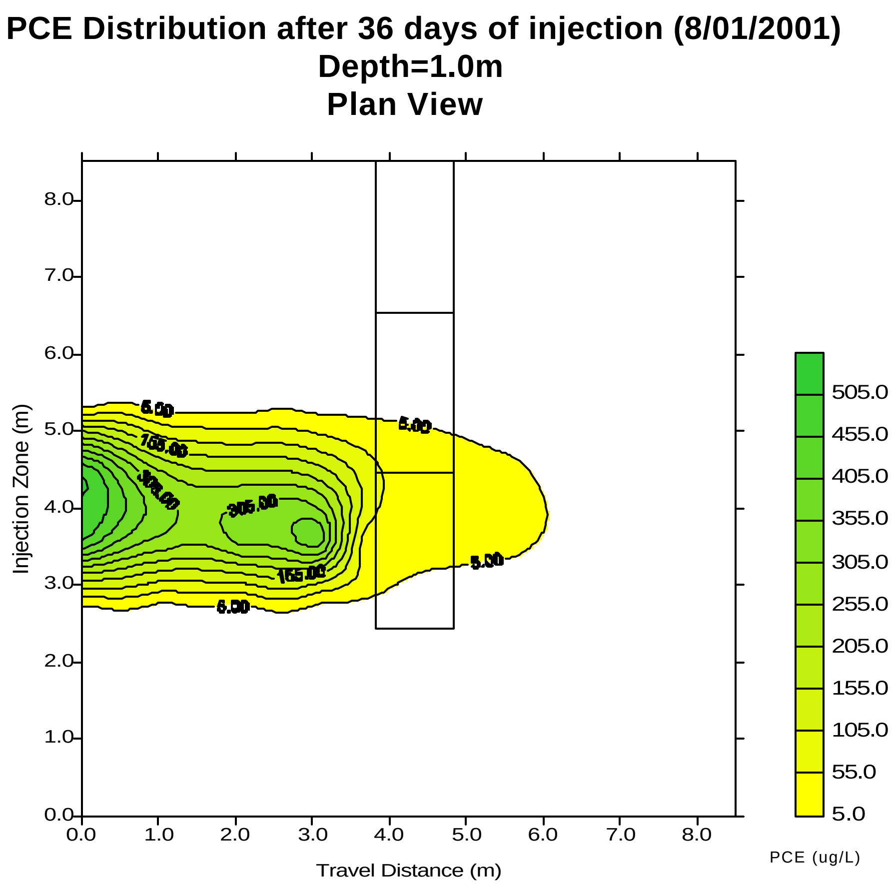


PCE Distribution after 29 days of injection (7/25/2001)
Depth=1.0m
Plan View



Cr and PCE Distributions, 5th week





Pilot Test vs. Lab Reduction Factors

(for a 1-m wide barrier)

Reduction Factor	PCE	CrO_4^{2-}
Lab R	1/10,000	>1/1000
Pilot Test R	1/100	>1/1000

Accomplishments of This Phase

DEVELOPED SMZ/ZVI PELLET TECHNOLOGY

- Simultaneously sorb/reduce contaminants
- Mechanically stable
- Highly permeable

PILOT-TESTED SMZ/ZVI PERMEABLE BARRIER

- Barrier fully captured contaminant plume
- Chromate reduced below regulatory limits
- PCE reduced two orders of magnitude

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Schedule of Current Phase

TASK	COMPLETION DATE
Optimize formulation	December 2000
Manufacture pellets	April 2001
Conduct pilot test	September 2001
Analyze results	October 2001
Topical Report	December 2001